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TECHNOLOGY FOR SATELLITE POWER CONVERSION

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Prepared for

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1. Introduction

The work performed in this reporting period has concentrated on the metal-oxide-metal (MOM) diode. The fabrication procedure outlined in the previous report [1] was modified, and successful production of diodes has been achieved. At the direction of the technical monitors, work on millimeter wave frequency rectennas incorporating known semiconductor diode technology has been initiated.

2. MOM Diode

The construction of the edge MOM diode follows the work of Hielblum et al [2]. The approach detailed in [1] begins with the deposition of gold probing pads to provide a non-oxidizing contact to test the dc characteristics of the diode accurately. A thin Ni patch capped with an insulating SiO_2 layer, shown in Figure 1, is deposited next to form the first half of the diode. With this patch in place, a controlled oxide growth on the side or edge of the Ni patch [2]. The other half of the diode, typically Ni, is deposited completing the conduction path from the oxidized edge of the Ni patch to the opposite gold probing pad. It is important in this step that the last metalization take place without exposing the newly oxidized surface to the atmosphere. Otherwise, the controlled oxidization process is wasted as the Ni would be further oxidized in the atmosphere.

Difficulty has been encountered in making the Ni-SiO_2 patch. In this step a Ni layer (1000 Angstroms) and then a SiO_2 layer (1800 Angstroms) are deposited over the gold pads. A negative photoresist process is used to etch the SiO_2 and Ni and leave the patch as shown in Figure 1. The difficulty in this step is undercutting or etching of the Ni layer beneath the SiO_2 cap. In most cases the undercutting is severe enough to remove the Ni layer completely or to remove enough to ruin the fabrication run.

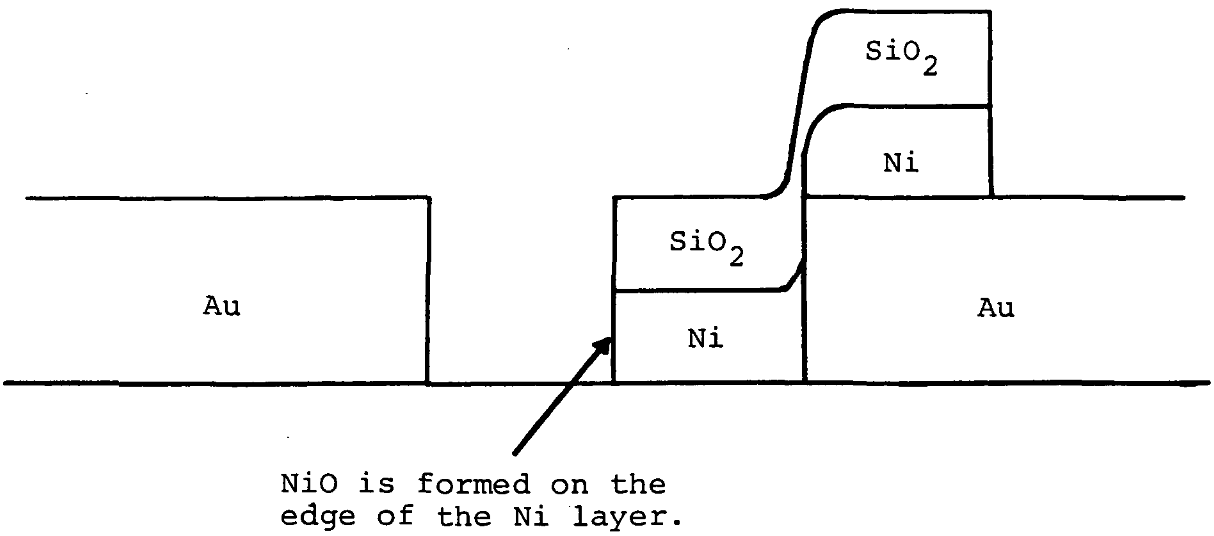

Figure 1. MOM diode after the second level metalization is complete. The Ni - SiO_2 cap is deposited over the Au probing pads. The third level metalization completes the path from the Ni patch to the opposite Au pad.

In contrast, the Ni-SiO_2 patch is easily processed if the gold probing pads are not present.

The problem seems to be a nonuniform etching of the Ni in contact with the gold. If the substrate is kept in the Ni etch long enough to remove all unprotected Ni, the majority of diodes are severely undercut, and if the etching process is stopped after the first diode patches are well formed, a majority of patches are not yet defined. Several possible causes for the nonuniform etching have been investigated. These include the concentration of the nickel etch, sputtering power of both the Ni and SiO_2 layers, and the substrate temperature during sputtering; however, varying these parameters has not resolved the problem. Other possible causes of the etching trouble are nonuniform exposure of the photoresist to UV light in the mask aligner and the structure of the gold near the nickel.

The requirements on the rectifying diode at millimeter wave frequencies are not as demanding as in the infrared region. In particular, the junction area and oxide thickness can be larger because the RC time constant can be larger at lower frequencies. MOM diodes with these changes have been made. The larger junction area is a result of eliminating the SiO_2 cap on the Ni patch. Without the SiO_2 layer, a positive photoresist step can be used in both the second and third metalizations (the Ni patch and the last half of the diode), thereby eliminating the troublesome Ni etch step. This modification increases the junction area in the diode, 50 to 100 square micrometers compared to 10 micrometers for the edge MOM. The larger oxide layer comes from allowing the Ni to oxidize naturally in the atmosphere. Ni-NiO-Ni and Ni-NiO-Cr diodes have been reported [3] with stable non-linear characteristics without using a controlled oxide growth.

These changes allowed both Ni-NiO-Ni and Ni-NiO-Bi diodes to be made. Photographs of the diode are given in Figures 2a and 2b, and the dc I-V characteristics are found in Figure 3a an 3b. The Ni-NiO-Bi diode did not produce a non-symmetric I-V curve as hoped, but it did display more non-linearity and had a greater forward bias voltage.

3. Fabrication Process

The details of the fabrication process are given in this section. The only departure from previous methods used in this reporting period are the deposition and etching of Ni and SiO_2. The dimension of the three level MOM diode are given in Figure 4.

Both the Ni and SiO_2 are sputter deposited in a Perkin-Elmer Randex model 2400. The Ni deposits at a rate of 110 Angstroms per minute at 500 watts in a 10 millitorr Ar atmosphere. The SiO_2 sputters at 1200 Angstroms per hour at 500 watts in a 15 millitorr 3% O_2 in Ar atmosphere.

The Ni etch used in this work consisted of

3.80 gm	$CuCl_2 \cdot 2H_2O$,
47.5 ml	37% HCl, and
95.0 ml	H_2O.

This stock solution is diluted with water to control the etching rate. The SiO_2 is etched with a 4:1 solution of NH_4F and HF.

4. Conclusions and Recomendations

MOM diodes have been successfully fabricated in this reporting period. Both Ni-NiO-Ni and Ni-NiO-Bi diodes show symmetric I-V characteristics. At the direction of the technical monitors, work has begun on monolithic rectennas using existing semiconductor rectifier technology at millimeter wave frequencies.

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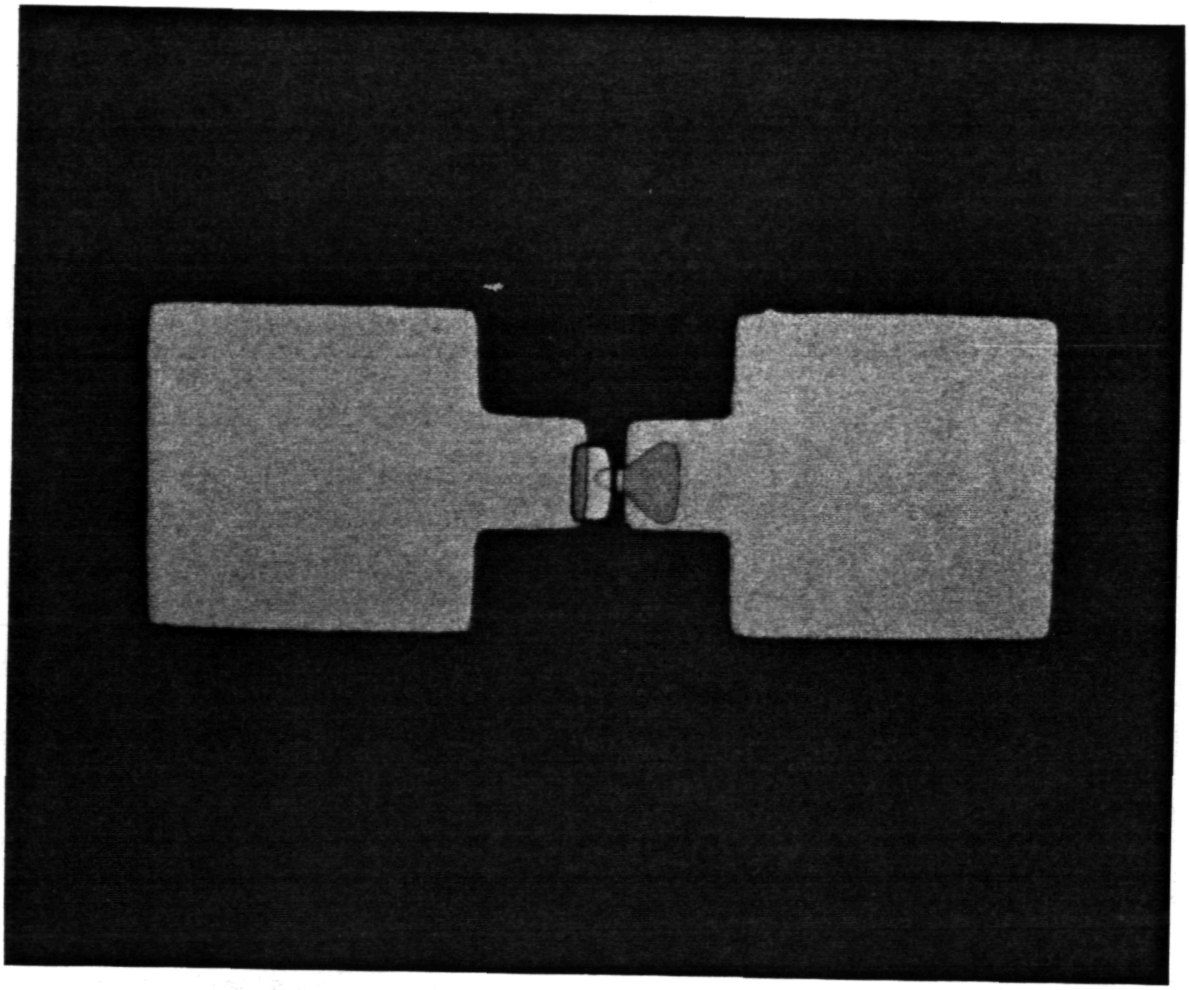

Figure 2a. Photograph of entire MOM diode structure including the probing pads.

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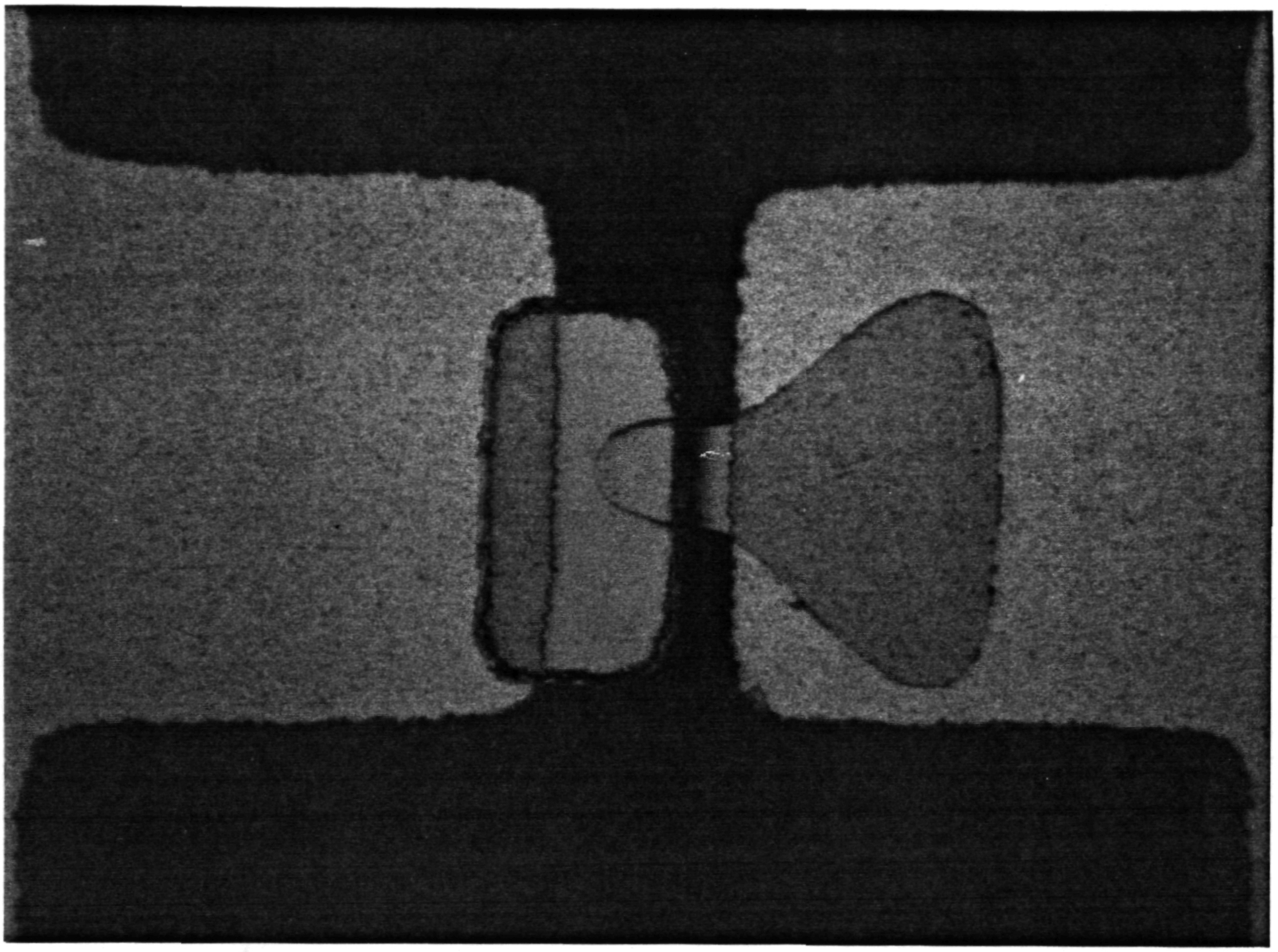

Figure 2b. Close-up Photograph of three level MOM diode structure. Dimensions for the diode are given in Figure 4.

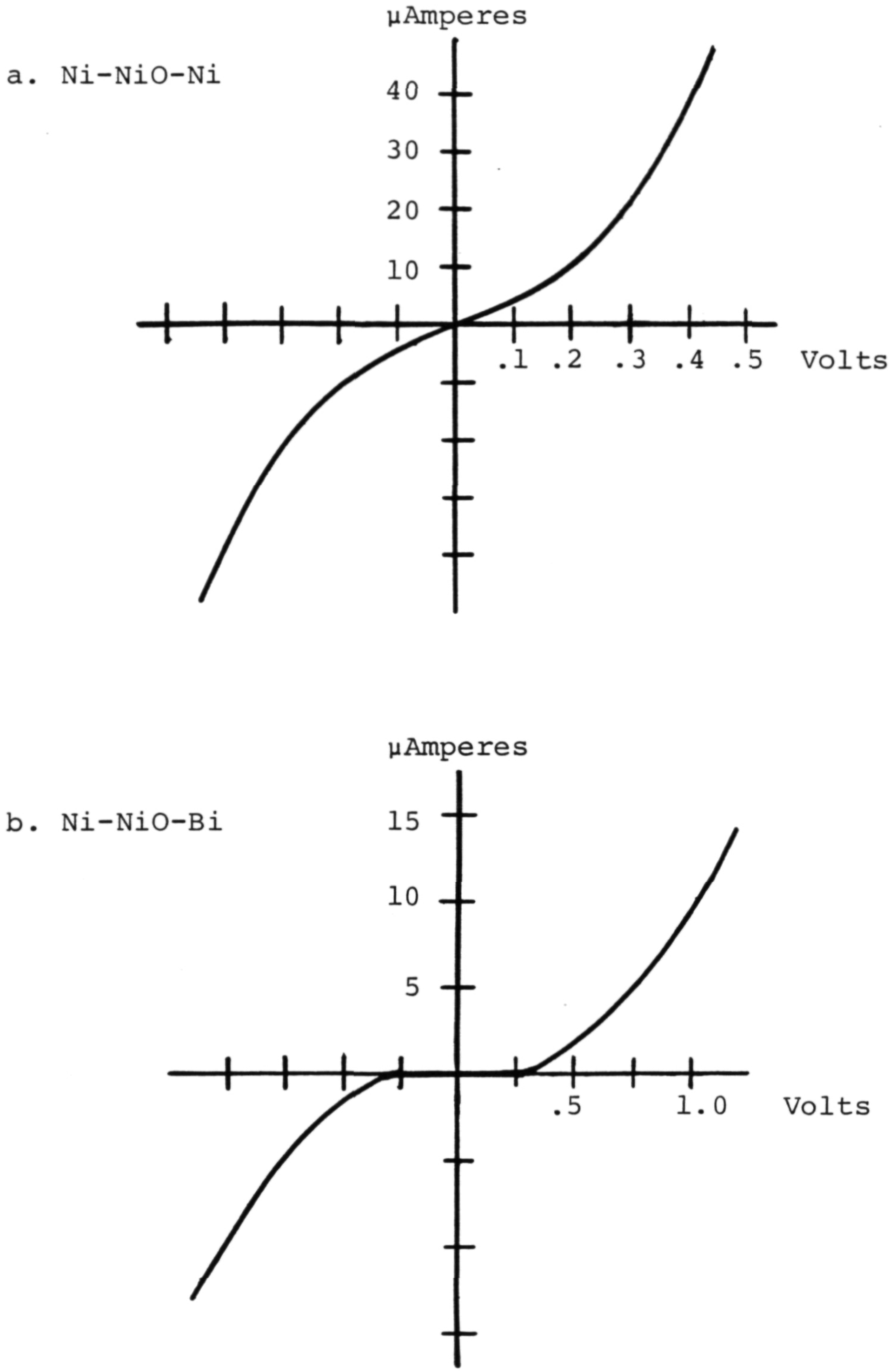

Figure 3. I-V curves for typical MOM diodes.

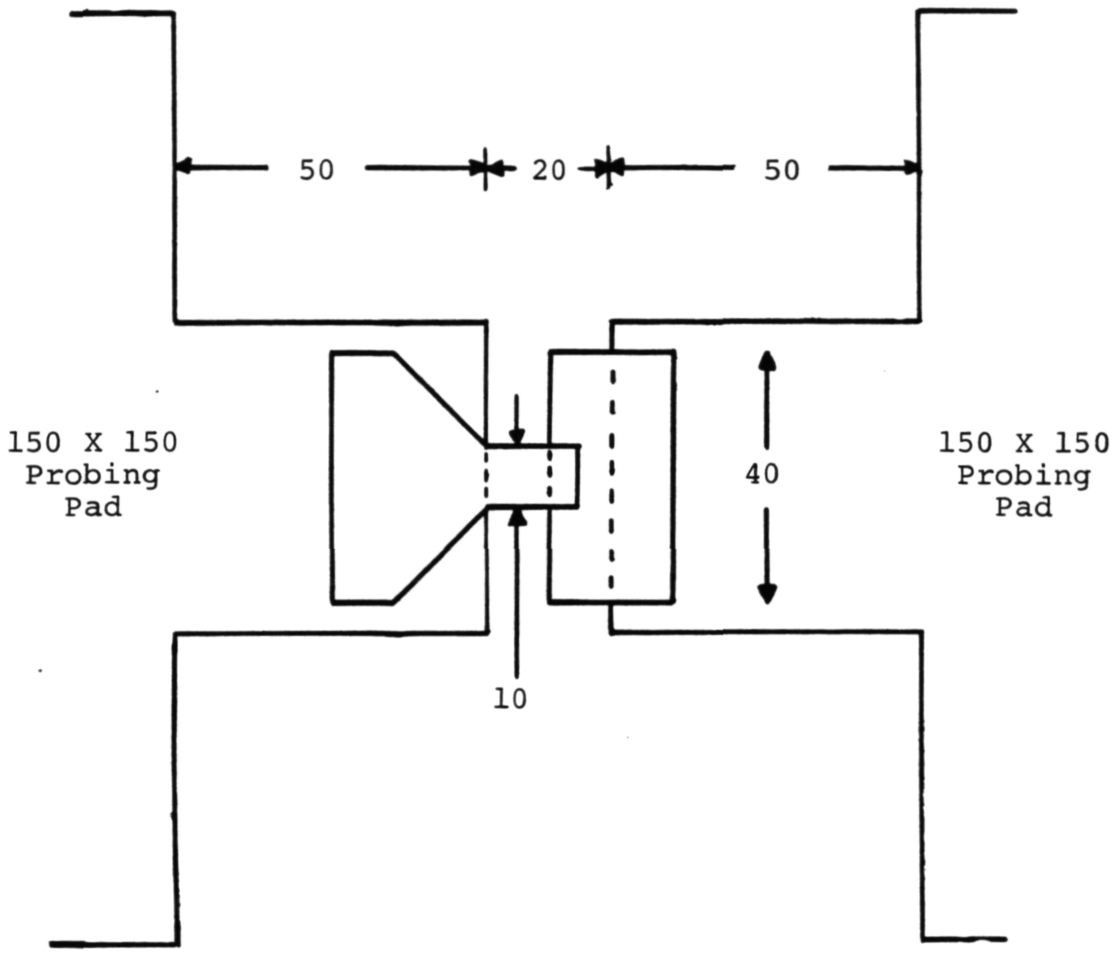

Figure 4. Three level MOM diode structure. All dimensions are in micrometers.

References

1. M. A. Gouker, D. P. Campbell and J. J. Gallagher, "Semi-Annual Satus Report on Technology for Satellite Power Conversion," January 29, 1986.

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3. J. G. Small, G. M. Elchinger, A. Javan, A. Sanchez, F. J. Bancher and D. L. Smythe, "AC Electron Tunneling at Infrared Frequencies: Thin-Film M-O-M Diode Structures with Broad-Band Characteristics," Appl. Phys. Lett., vol, 24, pp. 275-279, (1973).